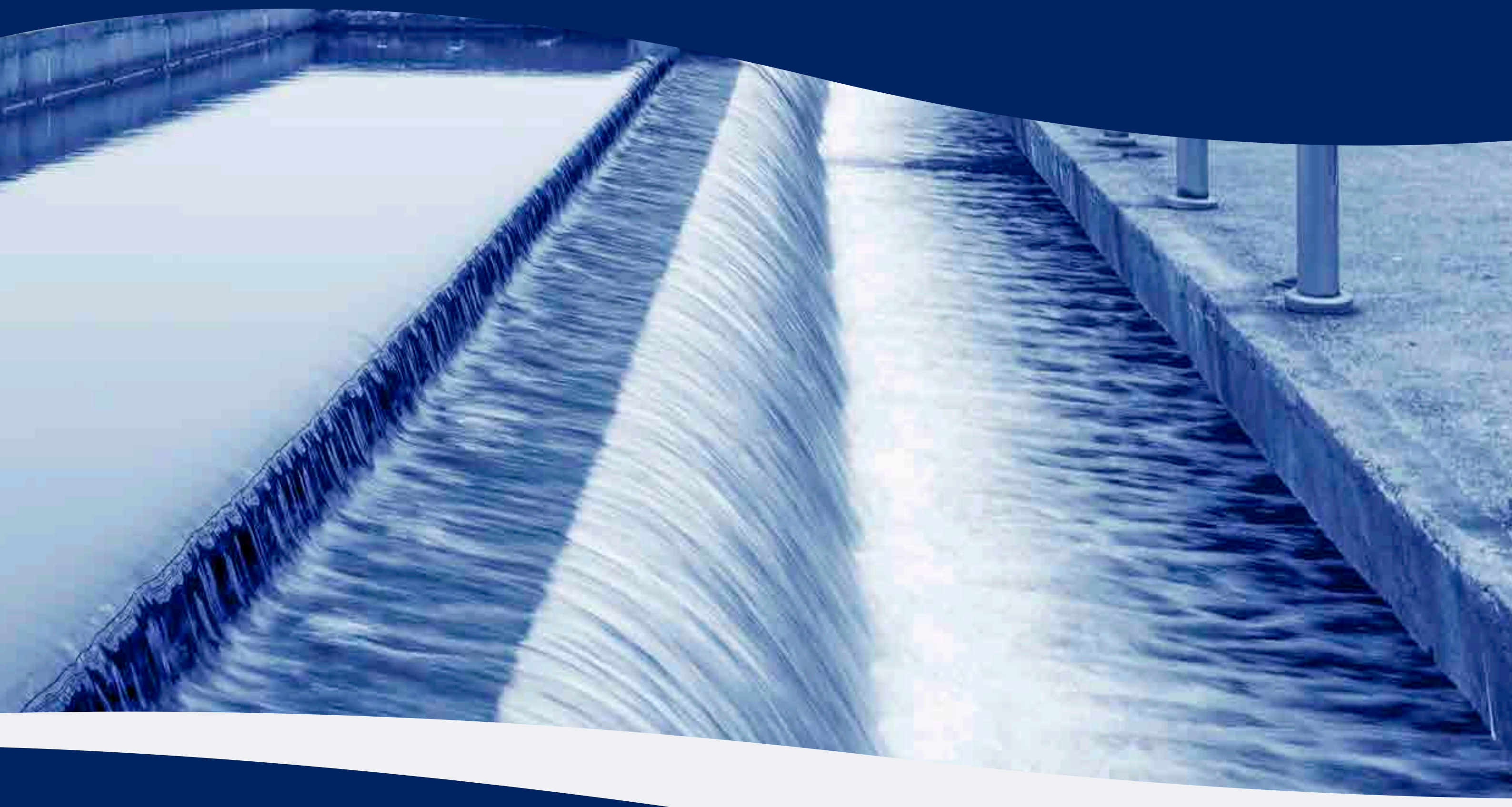
Balancing turndown considerations with TCO

A long-term cost analysis model for the wastewater treatment industry



Meeting **future** demands

As established in our first whitepaper, total cost of ownership (TCO) is a key consideration when choosing blower equipment for aeration in a wastewater treatment (WWT) plant. With some studies showing energy and maintenance costs can be as much as five times more than the initial capital cost for industrial equipment, it's clear that a considered approach to TCO can pay dividends.

In the WWT industry, this is further exacerbated by how energy-intensive the aeration process is, accounting for up to 70% of a plant's energy costs. This is why not solely focusing on how a blower system costs upfront is important. From the upfront purchase price, to on-going energy, maintenance, repair and service costs, TCO accounts for any spend throughout the entire lifetime of the equipment.

With the average lifecycle of a WWT plant being 20 to 25 years, specifying blowers for this length of service can prove to be a challenge. Decision makers not only need to plan for a plant's existing capacity, but for future growth too. And if we consider the solutions that were available 20 years ago and how dramatically technology has evolved since then, it's clear that selecting a solution for this length of time is not straight-forward.

A common problem we see is that many WWT plants end up over-sizing solutions to try to accommodate future demands, as well as lowering any risks of having a downsized plant. This however, is unnecessary and can be costly in terms of both the initial outlay and any on-going maintenance spend. While this approach may meet your plant's future needs and be the best solution on paper when it comes to TCO, it won't be optimised to meet the demands of your plant now, or in the next 5 to 15 years.

So, how can we address this challenge? By considering blowers' turndown in the selection process.

Turndown is an essential factor that can help accommodate changes in demand over a period of time. Nevertheless, turndown is consistently overlooked when specifying blower systems, and yet can have a big impact on a system's whole life costs.

As a result, we see this as being the second piece of the puzzle that we started to solve in the first whitepaper, *Price versus TCO*. In this whitepaper, we will discuss why turndown needs to be taken into account when purchasing a long-lasting blower solution for your WWT plant, outlining how to balance this consideration with TCO. The end result? The most efficient, cost-effective blower solution for your site, whether that's...

- Positive displacement rotary lobe blowers
- Screw blowers
- Turbo blowers, with centrifugal compression
- COMBO Or a combination of technologies

Tackling **turndown**

What is turndown?

'Turndown' refers to the blower's ability to reduce its air flow rate quickly and efficiently to meet the changing air demands of a site. Turndown considers the maximum and minimum blower or system flow rates, and could be written as the following equation...

$$\text{Turndown } \% = \frac{\text{Max capacity} - \text{Min capacity}}{\text{Max capacity}} \times 100$$

In essence, the greater the turndown, then the more flexibility a WWT plant has in handling unexpected demands. Operators need good turndown to protect the performance of their processes.

It is estimated that, for most of a WWT plant's lifespan, its aeration tanks will need less than the average daily flow rate of process air that was specified at the design phase. The impact this can have on a plant's TCO is significant. Therefore, choosing a blower with the right level of turndown available to meet your site's needs can make a big difference to your bottom line.

Greater turndown means a system is better equipped to meet a site's lowest air requirements, without wasting energy, while delivering the flexibility to achieve larger air demands at peak times or to meet long-term needs. In short, if a system cannot respond fast to periods of lower air demand with a reduced flow rate, then it is ineffective – even if you've specified blower solutions that generate air very efficiently on the whole. Ultimately, no matter how good the performance of a system is, having a blower or a system generate unnecessary air is still a significant waste of energy.

Another consideration is that greater turndown also provides more operational flexibility, enabling a system to effectively satisfy air demands with fewer blower units.

Forecasting for the future

Blowers are specified based on the dissolved oxygenation levels of an aeration tank, as well as factoring in data predictions based on future demand and projected 'worst-case' load scenarios. Once these figures have been determined, and budget constraints and key decision makers satisfied, a decision will be made.

Most designs will account for increased loading due to predicted population growth in the plant's service area. As outlined, this means that many blower technologies will be oversized from the outset. Therefore, for much of its early life, a WWT plant will be operating well below the average daily flow rate that a system will have been specified for.

While greater turndown provides the flexibility to meet these changing air demands, it's important to note that a change in flow rate will also change the efficiency of equipment. Therefore, when selecting blower technology, it's critical to have an understanding of the equipment's efficiency capabilities over time – over a 25-year period, to be precise.

And with a range of blower technologies available on the market, this adds another level of consideration. The architecture and design of each type of technology will further impact, limit and improve turndown over time, so this needs to be factored in when choosing a system too.

A **blow-by-blow** comparison of different technologies

1. Rotary lobe blowers

Available for a lower capital cost, a rotary lobe blower is an oil-free technology that uses two or three lobes and a main motor coupled with belt and pulley transmission. The system operates on the principles of isochoric compression, where air is generated without having been compressed inside the blower block. With the volume of air remaining constant inside the block and a reliance on external compression, these machines are generally less efficient than screw and turbo solutions.

Regardless, rotary lobe blowers are well-known for their reliable turndown range when sized properly to a site's demands and are often ideally suited to applications requiring medium to small air flows.

While available to purchase for cheaper than other technologies, rotary lobe blowers do tend use more energy during their service life, leading to greater operating costs for plants. Their simple design, however, means they are relatively low-cost to maintain.

2. Screw blowers

Screw technology uses a 3x5 or 4x6 profile rotor, and a main motor coupled with belt and pulley transmission. This oil-free technology boasts increased efficiency due to its internal compression, which can be further enhanced with a frequency converter. Nevertheless, screw technology can often see efficiency losses through its transmission, motors, gears and frequency converters, which means they can appear to be not as efficient as turbo technology.

However, what screw blowers do offer is a wide turndown range. This is essentially because a screw blower is what we would call a 'volumetric' machine, rather than a 'dynamic' one like turbo or centrifugal technology. A WWT plant's varying working pressure is easy for screw technology to handle, delivering a real benefit to sites that demand a wide turndown range.

Furthermore, the belt drive of a screw blower ensures the right capacity for the application in question, enabling it to operate at peak efficiency levels. A screw blower's efficiency is also proportional to its speed, whereas a turbo can use increased levels of energy consumption when it's not operating at a high enough speed, creating a surge.

3. Turbo blowers

Using a high-speed motor and drive, this oil-free technology is popular because of its high performance, taking advantage of either air foil or magnetic bearings to deliver excellent energy efficiency. With no mechanical efficiency losses and limited maintenance operations due to contactless transmission, it appears on paper that the turbo generally offers the best blower solution available. Why, then, might you need to think twice about whether this provides the most efficient solution?

When operating at its 'sweet spot' – the ideal pressure and flow specified by an engineer – the turbo's performance is impressive. But, when turndown is factored in too, it becomes apparent that the turbo will not always be operating in these optimal conditions. Once air demand fluctuates, the turbo blower will no longer be as efficient as perhaps first anticipated.

Environmental and site conditions can influence the turbo's performance too. Seasonal temperature swings and changes in air density or atmospheric pressure can affect efficiency levels. When faced with these climate changes, turbo technology will need to adjust its speed, moving away from its 'sweet spot' in terms of efficiency levels.

Even with all these considerations taken into account, the biggest factor determining the best blower for a WWT plant is its ability to cope with changing air demands throughout its lifespan.

Therefore, we will now consider a number of example scenarios, illustrating how each technology will perform throughout its lifetime in a WWT plant, based on changing air demands, turndown range and the design of each solution.

Turndown **scenarios**

The best means of analysing the correct blower technology is to compare different case scenarios. In the following example, we will examine a solution that has not considered turndown in the selection process, versus the same application where turndown has been specified - and then go on to explore the learnings that can be derived.

To illustrate the energy consumption and financial impact of both approaches, we will be using a fictional but realistic case study example, with two potential turndown scenarios.

Case study parameters

- Required design parameters for the aeration process
- Total flow capacity: 20,000 Nm^3/h
- Pressure: 800 mbarg
- Average yearly required aeration capacity: 8,000 hrs / year
- Operating years: 20
- Energy cost: 0,13 EUR/kWh

- **Scenario 1:** No fluctuation in total flow capacity considered during the blower selection process, with the decision made based on the case study parameters.
- **Scenario 2**: Fluctuation in flow capacity considered for the plant's operating years based on the following forecast:

Point #	Total flow capacity requirement (Nm^3/h)	Year
1	5,000 Nm^3/h	0 to 4
2	10,000 Nm^3/h	5 to 9
3	15,000 Nm^3/h	10 to 14
4	20,000 Nm^3/h	15 to 20

Both scenarios will be simulated where blowers will be selected considering specific application requirements.

Product selection

The most challenging requirement is to select blowers that will be able to meet system demand. Therefore, both scenarios present the same outcome from a blowers' configuration perspective, which is summarised below. Alternative technologies have also been considered, alongside a standby unit, as is typically required in WWT installations.

	Lobe technology	Screw technology	Turbo technology
Selection	3 machines + 1 backup	3 machines + 1 backup	2 machines + 1 backup

TCO scenarios calculations

For both scenarios, the total cost of ownership is calculated for a period of 20 years. Details of the calculation are presented below.

Scenario 1: fixed flow

In this case, only the most challenging flow requirement is considered in order to calculate the TCO. This reflects the expected cost of ownership if the blowers operate from day one and for the next 20 years at their design capacity.

	Lobe	Screw	Turbo
	3 machines + 1 backup	3 machines + 1 backup	2 machines + 1 backup
Capital investment	€ 230 000	€ 372 000	€ 343 000
Energy cost over 20 years	€ 14 914 000	€ 12 808 000	€ 11 956 000
Maintenance cost over 20 years	€ 30 000	€ 68 000	€ 40 000
Total cost of ownership over 20 years	€ 15 173 000	€ 13 247 000	€ 12 338 000

Blower technologies total cost of ownership comparison	TCO versus Lobe		-13%	-19%
	TCO versus Screw	13%		-7%
	TCO versus Turbo	19%	7%	

Different technologies offer a different TCO, which is essentially impacted by the energy cost over a period of 20 years. This will also take into account specific operator requirements, such as financial consideration or energy reduction programmes.

Scenario 2: variable flow

Here, the calculation accounts for the flow parameter variability, where flow demand increases gradually to match the increasing demands of the aeration process. As presented in the scenario parameters, a range of points have been considered to reflect the flow increase during the 20-year period. The calculations can be summarized as follows:

		Lobe	Screw	Turbo
		3 machines + 1 backup	3 machines + 1 backup	2 machines + 1 backup
Capital investment	Point #1	€ 115 000	€ 186 000	€ 229 000
Energy cost over 5 years		€ 950 000	€ 809 000	€ 748 000
Maintenance cost over 5 years		€ 3 000	€ 6 000	€ 5 000
Total cost of ownership over 5 years		€ 1 067 000	€ 1 001 000	€ 982 000
Capital investment	Point #2	€ 58 000	€ 93 000	€ -
Energy cost over 5 years		€ 1 899 000	€ 1 618 000	€ 1 495 000
Maintenance cost over 5 years		€ 5 000	€ 12 000	€ 5 000
Total cost of ownership over 5 years		€ 1 961 000	€ 1 722 000	€ 1 500 000
Capital investment	Point #3	€ -	€ -	€ 115 000
Energy cost over 5 years		€ 2 800 000	€ 2 414 000	€ 2 234 000
Maintenance cost over 5 years		€ 5 000	€ 12 000	€ 10 000
Total cost of ownership over 5 years		€ 2 805 000	€ 2 425 000	€ 2 358 000
Capital investment	Point #4	€ 58 000	€ 93 000	€ -
Energy cost over 5 years		€3 729 000	€ 3 202 000	€2 989 000
Maintenance cost over 5 years		€ 8 000	€ 17 000	€ 10 000
Total cost of ownership over 5 years		€ 3 794 000	€ 3 312 000	€ 2 999 000
Total cost of ownership over 20 years	All points	€ 9 625 000	€ 8 459 000	€ 7 838 000

Blower technologies total cost of ownership comparison	TCO versus Lobe		-12%	-19%
	TCO versus Screw	12%		-7%
	TCO versus Turbo	19%	8%	

Turndown total cost of ownership comparison	-37%	-36%	-36%

Points to note:

- The hypothesis was taken that the equipment's capital investment would be spread across the years, depending on the flow requirement. However, this is not always the case. While most WWT plants will typically install all the blowers needed throughout a site's 20-year lifetime, not all these systems will be required on day one. In fact, there's a good chance a site will switch off several of the units, to reduce energy costs. So, not only are there blowers not being used – but remember these will still require maintenance – there's also the upfront capital cost of these technologies that you need to consider. In contrast, a WWT plant would be better just purchasing the number of blowers it needs for a set period. The plant's consumption could be reviewed over time, with additional units purchased in the future to help increase the plant's capacity. This investment would be based on more accurate data, too. For the sake of this simulation, however, this does not represent an issue, as the analysis compares the TCO over a 20-year period and not during specific years.
- The TCO differences between the technologies are very similar to scenario 1. This is to be expected, as identical machines have been selected in both scenarios, and their capital and operating investments remain unaffected.

Scenarios comparison

When comparing both scenarios, some striking differences between the TCO results can be seen.

The significant difference (-37% for scenario 2 compared to scenario 1) comes from the fact that the blowers are utilised to a lesser extend in scenario 2, while in scenario 1 they are operating permanently at their design point. While the results of the TCO calculations are the same (the turbo technology presents the most interesting TCO, followed by the screw and then the lobe) it is worth noting that the expected overall investment is significantly lowered when considering the fluctuation of flow for the aeration process. This virtual saving would enable operators to invest in more expensive equipment options (such as the screw or turbo technology), further increasing TCO reductions through a quicker return on investment.

Also, when the capacity demand is considered over time, and not just in the worst-case scenario (which, in our example, is year 20), it may be that a solution for shorter period of time delivers a better solution, rather than trying to find the best solution for the entire 20-year lifetime of the plant. Additional units can then be installed as the plant's blower demands increase. It might even be that a mix of different blower technologies would help provide the best solution for your site.

As shown in the scenario comparison, the demand fluctuation has a significant impact on energy consumption. This offers a more realistic approach, compared to the worst-case scenario of running at maximum capacity demand from the beginning of the plant's operation.

Without changing the equipment selection process, we can determine the future blowers' predicted energy consumption, which underpins the argument for higher capital investment to support more efficient technologies and even lower TCO.

The **best** of both

Throughout this whitepaper, you'll have seen there is no 'one-size-fits-all' approach to choosing the right blower technology for your WWT plant. It will depend on a variety of differing factors, from the design of the blower system and site conditions, to air demands throughout the lifetime of the WWT plant and the turndown range of equipment during this time.

In order to specify the best blower solution for your site, you need to balance both turndown considerations with a TCO mindset, taking into account a plant's day-to-day demands, operating conditions and the available budget to determine which technology is the right one for you. Only by doing this will you be able to identify the most efficient and cost-effective long-term solution.

This is why it's so important to have the help and support of a trusted blower manufacturer and specialist, who can work closely with you to undertake a long-term cost analysis model for your WWT plant.

Once you've chosen the right blower solution for your plant, it's then critical that you take all the necessary steps to ensure your system continues to run as efficiently as possible. A robust and considered maintenance strategy can help achieve this.

In the next whitepaper in this series, we will be taking a look at blower maintenance – how you can implement a best practice maintenance strategy, to ensure the longevity of your blower technology, keep costs down and make sure that your system operates as efficiently as possible throughout its lifetime.

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marketing.robuschi@gardnerdenver.com